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ABSTRACT

This instructional guide, intended for student use, develops the topic of electronics through a series of sequential activities. A technical development of the subject is pursued with examples stressing practical aspects of the concepts. Included in the minicourse are: (1) the rationale, (2) terminal behavioral objectives, (3) enabling behavioral objectives, (4) activities, (5) resource packages, and (6) evaluation materials. The applications of electronics to hobbies are stressed. This unit is one of twelve intended for use in the second year of a two year vocationally oriented physics program. (CP)

CAREER ORIENTED PRE-TECHNICAL PHYSICS

Electronics As A Hobby

Minicourse

ESEA Title III Project

1974

dallas independent school district

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October 8, 1974

Nolan Estes
General Superintendent

This Minicourse is a result of hard work, dedication, and a comprehensive program of testing and improvement by members of the staff, college professors, teachers, and others.

The Minicourse contains classroom activities designed for use in the regular teaching program in the Dallas Independent School District. Through minicourse activities, students work independently with close teacher supervision and aid. This work is a fine example of the excellent efforts for which the Dallas Independent School District is known. May I commend all of those who had a part in designing, testing, and improving this Minicourse.

I commend it to your use.

Sincerely yours,

Nolan Estes

General Superintendent

NE:mag

CAREER ORIENTED PRE-TECHNICAL PHYSICS

ELECTRONICS AS A HOBBY

MINICOURSE

RATIONALE (What this minicourse is about)

If you make a survey of the electronic items in your home, you will quickly become aware of the importance of this field to the consumer and of the job opportunities for technicians. The items that you will identify readily are such things as radios, hair dryers, television sets, and hi-fi systems. The electronic devices that may not be so obvious include the control devices on various appliances (such as ranges, washing machines, air-conditioning systems, and the like) and the devices protecting the electrical components of refrigerators, vacuum cleaners, and other electrical systems.

A basic understanding of the skills required in electronics can prepare one for many hours of pleasure in electronics as a hobby; such an understanding can also be a valuable aid to the homeowner, enabling one to make simple repairs. Also, a basic knowledge of electronics can result in the avoidance of accidents from the mishandling of household electronics. Electronic repair rip-offs can also be avoided.

Amateur and citizen's band radio communication has been very popular for years and is a classic example of an electronics-based hobby. A person can buy radio equipment ready for use, or can buy it in kit form ready to build. Most kits on the market require relatively little initial electronics knowledge to construct, other than the types of skills that you will develop from this minicourse.

Keep a notebook during this minicourse to contain an account of the investigations, assignments, and construction projects required.

In addition to RATIONALE, this minicourse contains the following sections:

1) TERMINAL BEHAVIORAL OBJECTIVES (Specific things you are expected to learn from this minicourse)

2) ENABLING BEHAVIORAL OBJECTIVES (Learning "steps" which will enable you to eventually reach the terminal behavioral objectives)

3) ACTIVITIES (Specific <u>things to do</u> to help you learn)

4) RESOURCE PACKAGES (Specific instructions for performing the learning <u>Activities</u>, such as procedures, references, laboratory materials, etc.)

5) EVALUATION (Tests to help ~~you~~ to determine whether or not you satisfactorily reach the terminal behavioral objectives)
   a) Self-test(s), with answers to help you learn more.
   b) Final test, to measure your overall achievement.

TERMINAL BEHAVIORAL OBJECTIVES:

Upon completion of this minicourse, you will be able to:

1) make a good solder connection on wires.

2) understand the process by which "tinning" a surface with solder takes place.

3) be able to build a DC power supply using components that are relatively inexpensive.

4) know some safety procedures in working with electrical and electronic devices.

5) be able to compare price versus quality of various electronics components and systems to determine what the optimum purchase decision might be.

6) be able to evaluate problems with electronic and electrical devices (simple trouble-shooting) to determine when to call a repairman.

7) check the load on a circuit to determine whether it is safe to add another appliance.

8) determine in advance of purchase of an appliance the cost of operating that appliance.

ENABLING BEHAVIORAL OBJECTIVE #1	ACTIVITY 1-1	RESOURCE PACKAGE 1-1
Demonstrate to your instructor's satisfaction the ability to make a good solder connection. Also demonstrate an understanding of the "tinning" process, and why it works with certain materials and does not work with others.	Read carefully the "Heathkit Kit Builder's Guide" and read the instructions on how to solder. Then complete Resource Package 1-1.	"Soldering"
	ACTIVITY 1-2	RESOURCE PACKAGE 1-2
	Complete Resource Package 1-2.	"Using Solder"

ENABLING BEHAVIORAL OBJECTIVE #2	ACTIVITY 2-1	RESOURCE PACKAGE 2-1
Demonstrate familiarity with some methods of controlling the speed of electric motors in such applications as electric mixers, electric drills, and fans.	Complete Resource Package 2-1.	"Motors and Generators"
	ACTIVITY 2-2	RESOURCE PACKAGE 2-2
	Complete Resource Package 2-2.	"Motor Control"

ENABLING BEHAVIORAL OBJECTIVE	ACTIVITY	RESOURCE PACKAGE
ENABLING BEHAVIORAL OBJECTIVE #3 Demonstrate the ability to construct a DC power supply using relatively inexpensive components. Also identify some sources where one might be able to find usable components for this purpose without purchasing them.	**ACTIVITY 3-1** Complete Resource Package 3-1.	**RESOURCE PACKAGE 3-1** "The Design and Construction of a DC Power Supply" and tape recording, "Solid State Rectifier"
ENABLING BEHAVIORAL OBJECTIVE #4 Demonstrate a familiarity with the way electric energy is delivered to the home, with series and parallel circuits, how a home is wired, and some electrical safety features for the home.	**ACTIVITY 4-1** Complete Resource Package 4-1.	**RESOURCE PACKAGE 4-1** "Residential Power Transformer and Home Wiring"
	ACTIVITY 4-2 Complete Resource Package 4-2. Make a list of a number of electrical hazards one might encounter in the home.	**RESOURCE PACKAGE 4-2** "Home Electrical Repair"
	ACTIVITY 4-3 Complete Resource Package 4-3.	**RESOURCE PACKAGE 4-3** "Checking an Electrical Circuit Load"

ENABLING BEHAVIORAL OBJECTIVE #5	ACTIVITY 5-1	RESOURCE PACKAGE 5-1
Demonstrate the ability to make a price-quality comparison on electrical appliances.	Complete Resource Package 5-1.	"How to Buy an Appliance"
ENABLING BEHAVIORAL OBJECTIVE #6	**ACTIVITY 6-1**	**RESOURCE PACKAGE 6-1**
Be able to trouble-shoot a simple electrical appliance in order to determine where one should begin in the repair process.	Complete Resource Package 6-1.	"Trouble-shooting"
ENABLING BEHAVIORAL OBJECTIVE #7 (OPTIONAL)*	**ACTIVITY 7-1**	**RESOURCE PACKAGE 7-1**
(This objective is optional.) Demonstrate the ability to construct an electronic device from a kit.	Complete Resource Package 7-1.	"Kit Building"

RESOURCE PACKAGE 1-1

SOLDERING

To connect two electrical wires, remove some insulation from the wire ends, twist the bare ends of the wires tightly together, wrap the twisted connection (junction) with insulating tape; and the connection will probably work satisfactorily. There is also the possibility that the connection will not work satisfactorily, and the result could be a fire. Twisted wires do not make the best kind of connection because the cross section of a conductor is circular, and it is thus difficult to get a large amount of the surface of the wires to make good contact when the wires are twisted together. If the contact surface is too small, the electrical resistance of the junction will be high and the resistance heating can be appreciable when current is passed through the connection. Also, with smaller contact surface, the twisted wires are subject to loosening if the connection has to sustain vibration or other motions. If, however, the junction is soldered, the solder touches the entire surface of the metal ends of the wires and makes the junction a continuous, solid metal "block" with an unbroken surface and a very low electrical resistance.

You can see that in electronics, it is important that you develop the basic skill of making a good solder joint. In addition to safety considerations, poor solder connections account for many of the problems associated with certain electronics equipment. When a good solder connection is made, the tin in the solder will be <u>alloyed</u> (fused; "melted together") with the material that is being soldered.

RESOURCE PACKAGE 1-2

USING SOLDER

The Kit Builder's Guide that is included in this minicourse provides instruction in basic soldering techniques. Read carefully what it says about soldering, then get a soldering tool and some solder from your teacher, and practice this basic skill. You will probably not be successful the first time you try to solder, but keep at it until your teacher agrees that you have done a good job. Be careful not to burn the table tops; use the special areas your teacher designates.

By now you have learned to solder and have learned to determine whether or not a soldered connection is satisfactory. You will probably have noticed that when a good solder connection has been made, the solder seems to be bonded to the metal of the wires so tightly that it really seems to have become a part of the metal soldered. In fact, the solder actually does become a part of the metal being soldered. Tin is a metal in solder, and tin forms an alloy with the surface of whatever other metal is being soldered. Tin is used because it is a metal which alloys readily with many different kinds of metals. Consider copper wire as an example. Tin alloys with copper to form bronze. Therefore, a layer of bronze will form between the copper wire surface and the solder surface. Thus the bronze is truly a part of <u>both</u> the copper and the solder. Lead is commonly included in solder for the purpose of lowering the solder's melting point, and to give solder a wide temperature range over which it is neither in the liquid nor the solid state, so that it can be worked readily. (Such a mixture of tin and lead is called a <u>eutectic solution</u>.)

It would be nice at this time to include an activity that would allow you to investigate the actual existence of the layer of bronze between the copper and the solder. However, this seems to be an impossible task. We have not been able to devise an experiment to prove or to observe the formation of the bronze, using equipment that one would have in the high school physics laboratory. In the event that you think of something that might show this phenomenon, please discuss it with your teacher.

You can, however, make some solder and see how the eutectic solution causes the melting point of the alloy to be lower than the melting point of either of the component materials. Make several different ratios of tin to lead, and see if you can determine any differences in the properties of the resulting solder. You can readily melt the tin and lead together, by using a "Meeker" burner and a porcelain crucible. Write a short account of this in your notebook.

RESOURCE PACKAGE 2-1

MOTORS AND GENERATORS

Electric motors and generators are basically the same device. A generator converts mechanical energy into electrical energy. A motor converts electrical energy into mechanical energy. Whenever a conductor cuts across a magnetic field, a current is set up in that conductor. If you examine the Miller-Cowan Dynamo Electric Machine of Fig. 2-1 on next page, you can readily see how a generator (motor) is constructed. In this device, the magnetic field is set up by an electromagnet. As a coil of wire (the armature winding) is moved across the field established by the electromagnet, electric current is set up in the armature coil. This current will be alternating in direction because as one end of the armature passes away from the north magnetic pole of the field the other end passes away from the south magnetic pole, and current is set up in a given direction. However, after the armature has made one-half revolution, the polarity is reversed because each respective magnetic pole now passes toward a pole having polarity OPPOSITE to the one it just left and the current flow is now in the opposite direction. The direction of current must therefore reverse every half revolution of the armature.

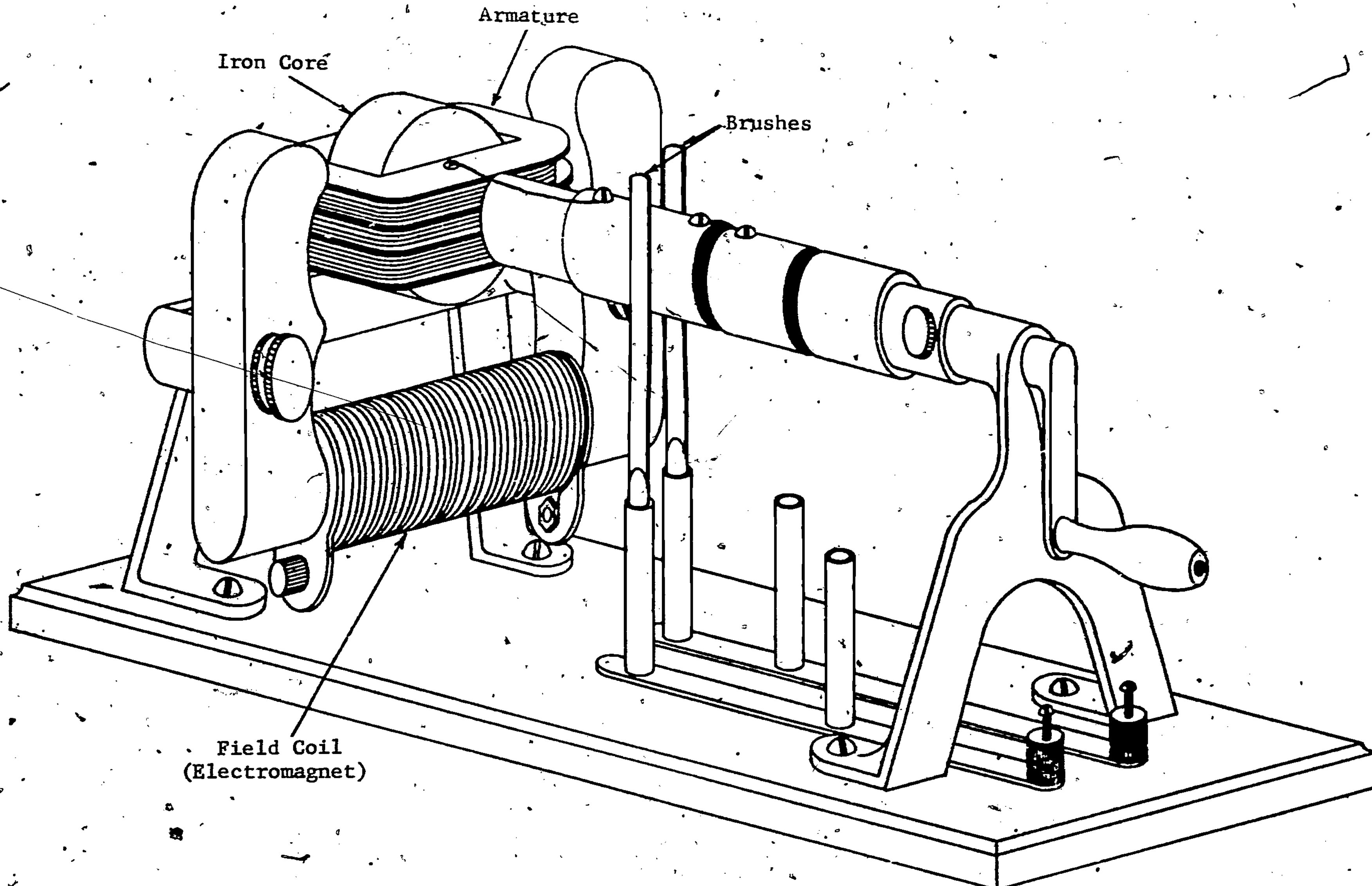


Fig. 2-1
A DYNAMO

You can see, then, that this generator produces only alternating current (AC) and the frequency of alternation will depend on the rate at which the armature is rotated. There are several ways to change AC to direct current (DC). Resource package 3-1 deals with this changing of AC to DC; a change to DC is called rectification. One way the current can come from the generator as DC is to use a rectification device called a commutator. If you look at the picture of the generator, you will see a ring around the crank shaft upon which brushes (electrical contacts) ride. This ring is separated into two sections, with insulation between them. One half of the ring is connected to one end of the armature coil, and the other half is connected to the other end. As this split-ring commutator revolves, the connection with the brushes reverses every half revolution. This reverses the current direction of every other half cycle of the generated current, and gives a pulsating DC current. On older cars, the generator was one of this type. In modern autos the current is taken out of the generator as alternating current (the device itself is called an alternator) and is changed into DC by a solid state rectifier that is much more efficient and longer lasting than the mechanical commutator.

The DC electric motor constitutes exactly the same type of device as the DC generator. The operation differs essentially in that current is passed through the commutator to the armature, which changes DC to AC and the consequent changing electric field causes ~~the armature~~ to turn (the "reversed" generator becomes a motor).

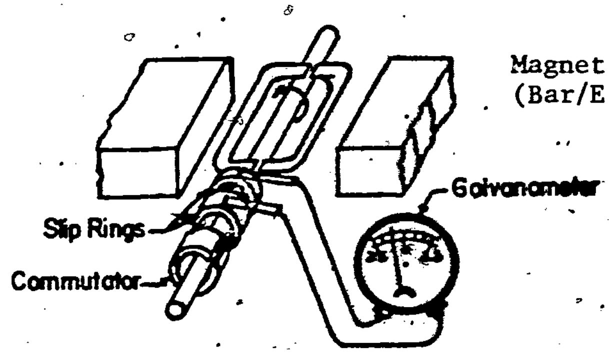
The following exercises should serve to acquaint you with DC motors and generators.

EXERCISE I

MATERIALS: (1) Miller-Cowan Dynamo Electric Machine, (2) St. Louis Motor equipped with both bar magnets and electromagnets (see Figs. 2-2 and 2-3), (3) galvanometer, (4) DC voltage source (6 volts), and (5) connecting wire. (NOTE: If the model generator in item #1 is not available, most of the experiment can be performed with a St. Louis Motor.)

INSTRUCTIONS:

1. Examine the picture of the generator model below:



ST. LOUIS MOTOR
Fig. 2-2

2. Connect a source of 6v DC to the field magnet of the generator.

3. Using the slip ring connections, connect the terminals of the brushes to the galvanometer.

4. Be sure that the armature coil is in a plane perpendicular to the electromagnetic lines of force set up by the field magnet (your instructor can help you with this). With the iron core in the center of the armature coil, turn the armature in a clockwise direction through a 180° arc. Notice the direction of the deflection of the needle of the galvanometer and the position of the rotating armature when the galvanometer needle is deflected a maximum.

5. Rotate the armature through another 180° arc, and again notice the behavior of the galvanometer needle.

6. Now rotate the armature continuously through several complete revolutions, watching the galvanometer needle carefully.

7. Repeat Steps 3, 4, and 5, without the iron core in the center of the armature. Notice the difference in the behavior of the galvanometer needle. Write a statement of this observed difference in your notebook.

8. Repeat Steps 3, 4, 5, and 6 by rotating the armature counter clockwise (opposite to the preceding directions). Compare the two rotational directions, in terms of galvanometer needle deflections.

9. Use the commutator and repeat the above procedure.

10. Disconnect the power source from the field magnet. <u>Connect the field magnet to the brush terminals.</u> Rotate the armature and notice the galvanometer needle (if there is no deflection of the galvanometer needle, reverse the electromagnet connections). This method is used in many DC generators for providing the magnetic field; it is called <u>self-excitation</u>.

QUESTIONS (Put the answers in your notebook):

1. Describe how current was produced in this activity.

2. What are three essential parts of a generator?

3. What type of current is always produced in a coil rotating in a magnetic field?

4. What factors determine the strength of an <u>induced current</u> (a current produced by moving a conductor across a magnetic field)?

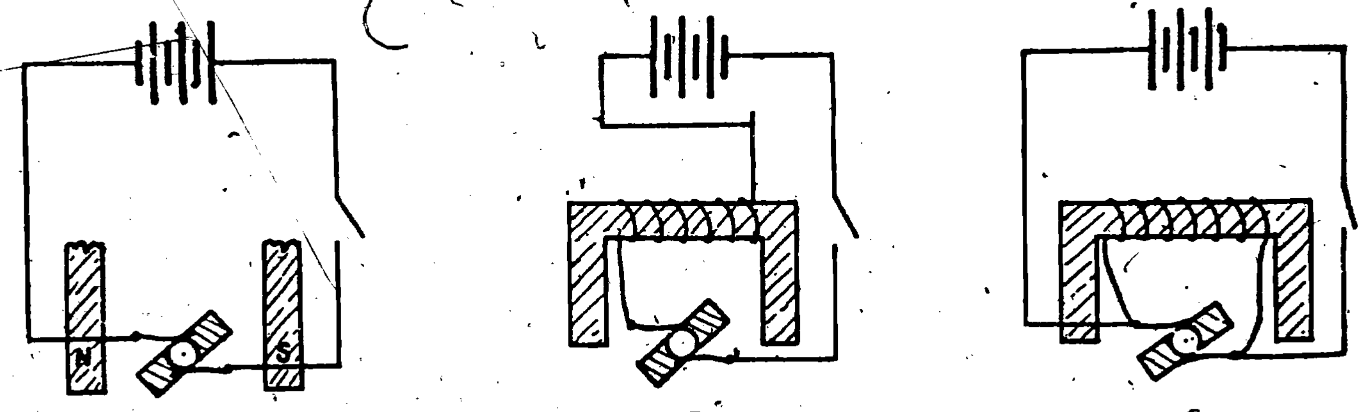
5. What was the effect of changing the direction of rotation?

6. How was direct current produced?

7. What was the effect of the iron core inside the armature?

EXERCISE 2

MATERIALS: Those described in Exercise 1.



ST. LOUIS MOTOR
Fig. 2-3

PROCEDURE II:

1. Assemble the St. Louis Motor, using the bar magnets as field magnets. Connect the source with the armature brushes, and adjust the brushes until the point of point of contact is half way between the magnets (See Fig. 2-3A). Close the switch and notice the results.

2. Stop the armature. Remove the magnets, and hold a compass over one end of the armature core. Notice its polarity. Rotate the armature slowly through at least one complete revolution, and test its polarity as it moves. Notice the position at which a reversal of polarity occurs.

3. Replace the magnets, and notice the direction of rotation of the armature. Compare the pole of the armature with the field pole it is approaching. Do the same thing just after it has passed a field pole.

4. Reverse the connections at the brushes and notice the effect.

5. Remove the bar magnets and replace them with the electromagnetic field. Connect the wiring as shown in Fig. 2-3B. The motor connected in this manner is called a series-wound motor. Close the switch and notice the direction of rotation. Knowing that rotation is always to the right, determine the polarity of the field magnet.

6. Reverse the direction of current from the power source. Notice the directions of rotation.

7. Cut the source power to 4 volts and notice the results.

8. Disconnect the field wires and connect them to the brush terminals; your set up should look like that in Fig. 2-3C. Slowly increase the power to the brush terminals and observe the results. Observe that the armature and the field circuits have been connected in parallel. Motors connected in this manner are called shunt-wound motors. Close the switch and notice the direction of rotation of the armature.

9. Reverse the field connections and notice the results.

10. Leaving the field connections reversed, reverse the connections at the source. Notice results.

11. Again, reverse the field connections and notice results.

QUESTIONS (Answer these in your notebook):

1. What are three essential parts of the direct current motor?

2. Explain how the armature of a DC motor rotates.

3. What is the result of increasing or decreasing the applied voltage to the armature of the DC motor?

4. How can the direction of rotation be reversed?

5. What happens if the direction of the current in both the armature and the field is reversed at the same time? Explain.

6. Under what conditions might you want to change a parallel-wound motor to a shunt-wound motor?

RESOURCE PACKAGE 2-2

MOTOR CONTROL

Included with this Resource Package are two Texas Instruments Application Reports. They report on control of the speed of electric motors. Most of the materials mentioned in these reports will not be available to you, so experimentation will not be practical.

Carefully read these two application reports, "Economical Reversible DC Motor Control" and "Fan Motor Thermostatic Speed Control." As you read them, make a list of possible applications for these two speed control processes.

RESOURCE PACKAGE 3-1

THE DESIGN AND CONSTRUCTION OF A DC POWER SUPPLY

EXERCISE I: <u>HALF-WAVE DC POWER SUPPLY</u>

There are many reasons why we might need to change alternating current (AC) to direct current (DC). These reasons might include charging a car battery, running an electric razor, driving an electric train, etc. DC circuits always have current (charge carriers) moving in one direction; DC is necessary for charging a battery, for example. AC circuit charge carriers change their direction on a regular basis; in the U.S., most households operate from AC systems which reverse current direction 60 times each second.*

Electricty is delivered to the home as alternating current for reasons of economy and efficiency which will be covered later. For now, the purpose is to see how AC can be changed to DC; changing AC to DC is called rectification. The first rectification was done with a radio vacuum tube, using a principle called the Edison Effect. This tube makes use of the fact that when a piece of metal is heated electrons will "boil off" its surface much like water molecules leaving the surface of boiling water.

If a positively charged metal plate is placed in the vicinity of the piece of metal that is heated and emitting the electrons, these electrons (being charged negatively) will be attracted to the positive

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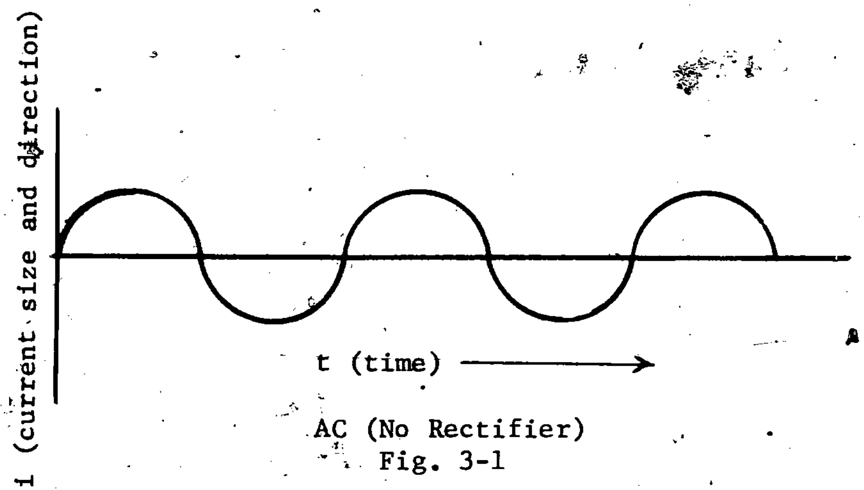
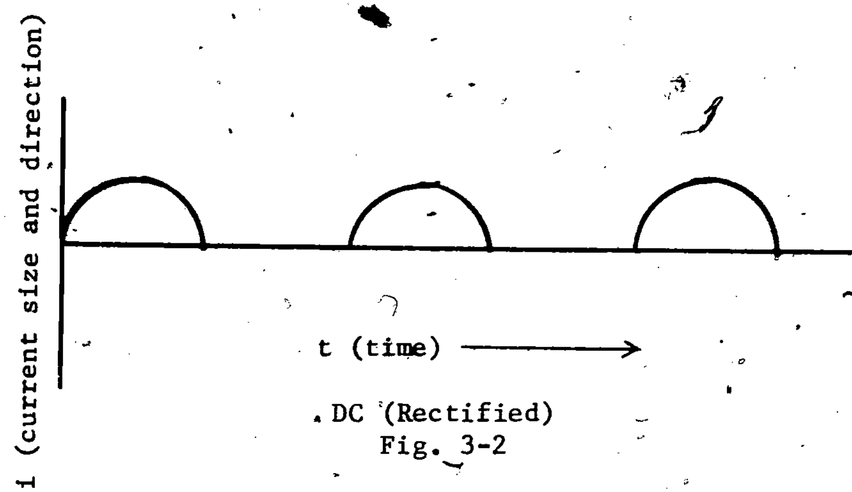
* Equivalent: 60 cycles/second (60 cps); or 60 hertz (60 hz).

plate. There will be, however, no ~~tendency for electrons to~~ pass in the opposite direction (since the plate is not heated no electrons will "boil" out of its surface). If this device (heated metal and positively charged plate) is placed in an electrical circuit it will act as a one-way valve, allowing current to pass through the tube circuit only when the plate is positively charged, while not allowing any current to pass when the plate is negatively charged.

Figure 3-1 shows how a graph of alternating current plotted against time would look.



AC (No Rectifier)
Fig. 3-1



DC (Rectified)
Fig. 3-2

You can see from the graph (Fig. 3-2) that the current is in one direction, rather than in two directions (as in Fig. 3-1). Notice that the DC is in pulses. In Fig. 3-2, the <u>bottom</u> part of the curve in 3-2 has been rectified and the current pulses are all in the same direction above the line (the AC of Fig. 3-1 has been rectified). In actual practice, rectifiers and related devices result in many

"humps" above the line and a set of smooth pulses which approach being a straight line (a "level" DC output).

An old television set can supply a wealth of parts, with which you can construct a DC power supply. You should have little trouble finding an old television set from which to take parts in order to continue this activity. Ask your teacher for help, if needed.

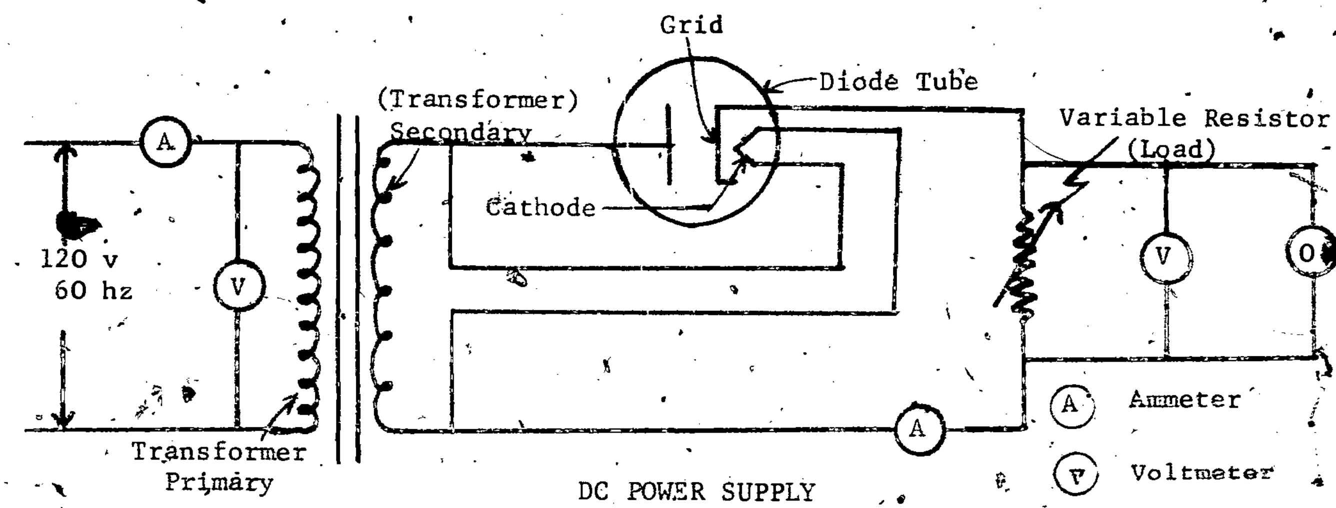
Examine the old TV set. Identify the filament transformer, diode tubes, and capacitors. These will be the components that you will use in the construction of your first power supply. They will be described below. Your teacher can help you with your identification.

Gather together the following materials:

1) filament transformer
2) diode tube
3) RCA tube manual
4) connecting wire
5) AC voltmeter
6) DC voltmeter
7) oscilloscope
8) 20-ohm variable resistor
9) AC ammeter
10) DC ammeter

First, examine the tube manual. You will see that a wealth of data about your diode tube is there. Next, choose a diode that has the same filament voltage as the secondary side of the filament transformer. The filament is the part that heats the cathode (negative side) of the tube to cause it to emit electrons. If the voltage supplied to the filament is higher than the rated voltage of that filament, the filament will burn out.

1) Connect the circuit as shown in Figure 3-3. <u>Do not connect the source of AC power until your instructor has approved the circuit.</u>



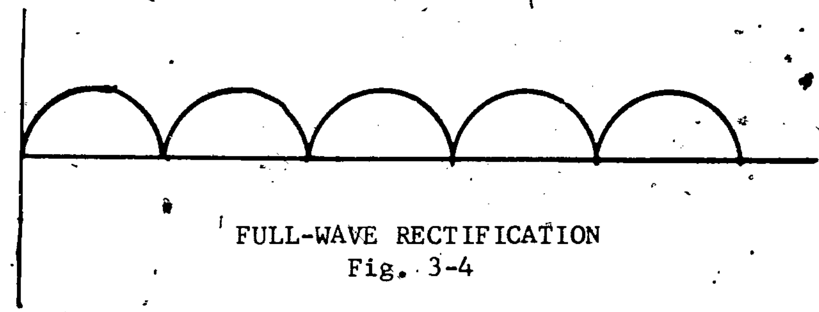
DC POWER SUPPLY
Fig. 3-3

2) Observe the oscilloscope trace. See that you get only the half wave form shown in Figure 3-2. You can also guess that the current has been changed into DC by the fact that it is read on a DC ammeter.

3) Assume that the power in this circuit can be calculated as the product of current times voltage ($P = IV$). Calculate the power used by the load resistor and record this calculation in your notebook.

EXERCISE II: THE FULL-WAVE VACUUM TUBE POWER SUPPLY

The most desirable situation in rectification of an AC signal is to use the pulses that exist in the direction of the top of Fig. 3-1, but also to take the pulses going in the opposite direction and "turn them around" so as to make them also go in the direction toward the top of the graph.



FULL-WAVE RECTIFICATION
Fig. 3-4

Figure 3-4 shows what a graph of this might look like. Compare Fig. 3-1 to Figs. 3-2 and 3-4; figure 3-4 represents full-wave rectification. To accomplish full-wave rectification, one could use either two diodes or a dual diode (A dual diode is simply two diodes in the same envelope) in the circuit of Fig. 3-3.

The transformer you will need must have a center tap (terminal, or outlet) on the secondary coil. You may have to purchase it if you cannot find one in a TV set. Ask your teacher.

Now gather together these materials:

1) step-down transformer, with center tap on the secondary
2) two diode tubes, or one dual diode tube
3) RCA Tube Manual
4) connecting wires
5) AC voltmeter
6) DC voltmeter

7) AC ammeter

8) DC ammeter

9) variable resistor

10) oscilloscope

INSTRUCTIONS:

1) Connect the circuit as shown in Fig. 3-5, page 27. Do not connect the circuit to the source before your instructor has approved it.

2) Observe the oscilloscope. Can you see the full-wave rectified form shown in Fig. 3-4?

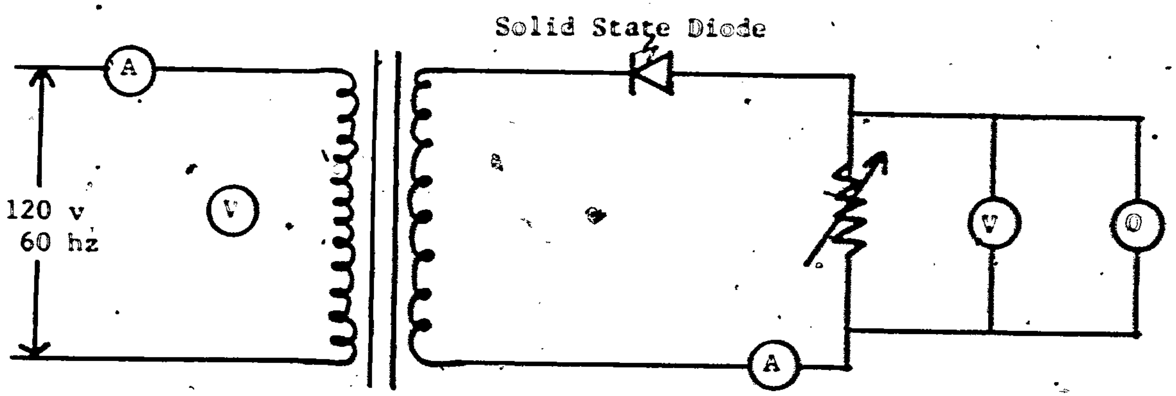
EXERCISE III: HALF-WAVE SOLID STATE RECTIFICATION

The efficiency of rectifier circuits using vacuum tubes is rather low. One might expect this since the energy used to heat the filament does not enter into the power output of the tube, but simply causes the electrons to be boiled out of the cathode and their energies to be dissipated as heat into the surroundings. In fact, if one has a large number of vacuum tubes in one location, additional energy will have to be used to remove the excess heat from the area in order to keep the circuit functioning.

The solid state diode does not present this heating problem, but acts as a low-temperature one-way valve for the circuit electrons. To see how such a diode works, consider the materials of which one is constructed. Before you continue with this exercise, listen to tape #2-1 on solid state rectifiers.

Now gather together these materials:

1) filament transformer
2) solid state diode
3) variable resistor
4) AC ammeter
5) AC voltmeter
6) DC ammeter
7) DC voltmeter
8) oscilloscope
9) connecting wires



SOLID STATE DIODE DC POWER SUPPLY
Fig. 3-5

INSTRUCTIONS:

1) Connect the circuit as shown in Fig. 3-5. Do not connect the source of AC until your instructor has approved the circuit connections!

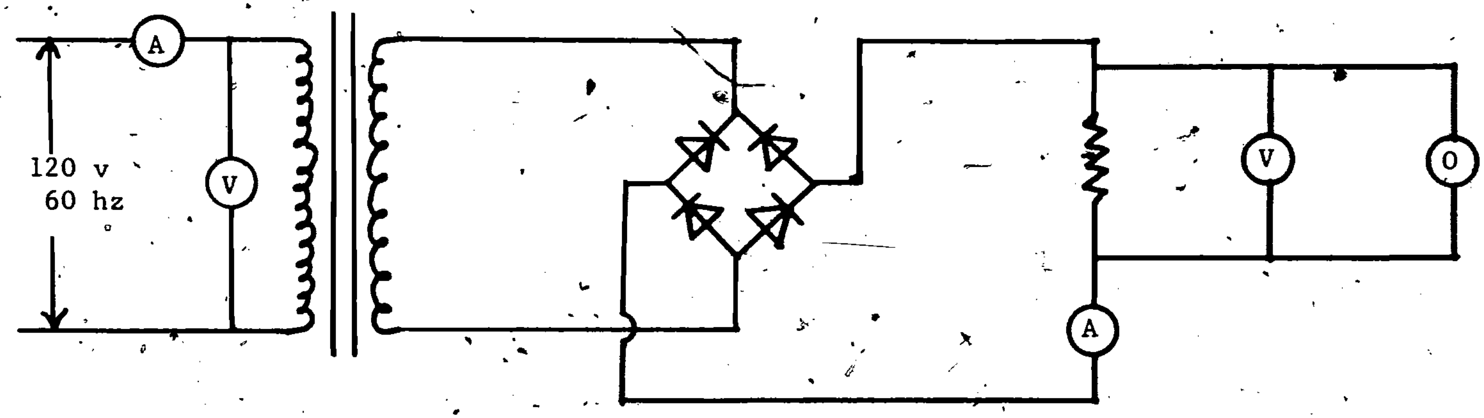
2) Look at the oscilloscope. You should see the half-wave pattern shown in Fig. 3-2.

EXERCISE IV: FULL-WAVE SOLID STATE RECTIFICATION

Compared to vacuum tubes, solid state rectifiers are inexpensive. At some radio supply stores you can buy a package of a dozen for a dollar or less. This is not the case with vacuum tubes. They cost several dollars each. In considering construction economy, one needs to use as few vacuum tubes as possible; but it makes little difference how many solid state diodes one uses. For this circuit we will use a "bridge" (see Fig. 3-6) of four diodes. When a bridge is used for full-wave rectification, one does not need to use a center-tapped transformer (which is more expensive than one that does not have a center tap).

Assemble the materials:

1) Filament transformer
2) Four matched solid state diodes
3) Variable resistor
4) AC ammeter
5) AC voltmeter
6) DC ammeter
7) DC voltmeter
8) Oscilloscope
9) Connecting wires



FULL WAVE SOLID STATE RECTIFIER CIRCUIT
Fig. 3-6

INSTRUCTIONS:

1) Connect the circuit, as shown in Fig. 3-6. Do not connect the AC power until your instructor has just approved the circuit. Also, when you finish working with this circuit, do not disconnect it. (You will need only to add on to it, for Exercise V.)

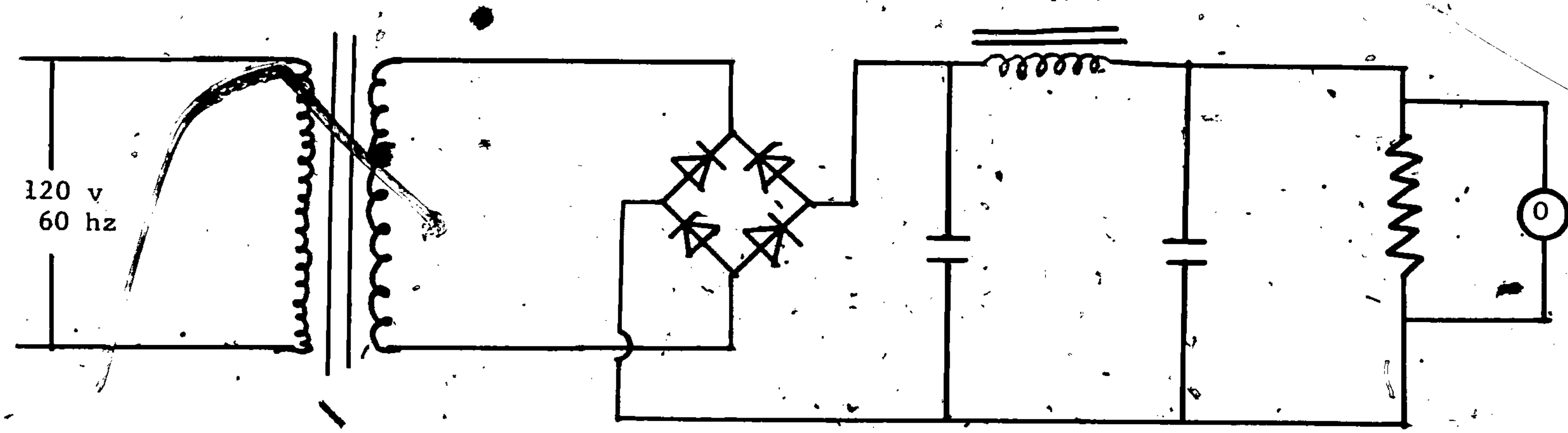
2) Observe the wave form on the oscilloscope. (It should look like the one in Fig. 3-4.)

EXERCISE V: ELECTRICAL FILTRATION

Up to this point you have worked with pulsing rectifier circuits, but the pulsating DC of these circuits (even from the full-wave circuit) is not acceptable for many applications. In order to produce DC that closely approximates a steady, constant voltage and current, it is necessary to "chop the top off" the pulses, store these, and then release them during the time intervals when the voltage (current) starts to go down. This may be accomplished with the addition of capacitors and coils to the circuits used previously. In fact, the circuit that will be used in this exercise will be the one you constructed in Exercise IV.

GET THESE MATERIALS TOGETHER:

1) full-wave bridge rectifier circuit (constructed in Exercise IV).
2) two capacitors
3) choke coil (NOTE: If a choke coil is not available, one may be constructed by wrapping 100 turns of insulated copper wire around a ¼ x 3" bolt.)



PI-SECTION FILTER CIRCUIT
Fig. 3-7

INSTRUCTIONS:

1) Fig. 3-6 shows the full-wave bridge rectifier circuit without the filter network added. Set up the circuit as shown. Have the instructor check your circuits. Observe the wave form and sketch it in your notebook.

2) Now look at Fig. 3-5. Add one of the capacitors to the circuit. Make a sketch of the wave form now seen on the oscilloscope.

3) Now add the second capacitor. Make a sketch of the wave form on the oscilloscope and note that this is without the choke coil.

4) Now add the choke coil to the circuit. Make a sketch of the wave form on the oscilloscope. This type of circuit filter is called a π-filter.

QUESTIONS:

1) Give a qualitative description of the operation of a solid state diode.

2) Describe the Edison Effect.

3) Describe the operation of a full-wave bridge rectifier circuit with a π-section filter.

RESOURCE PACKAGE 4-1

RESIDENTIAL POWER TRANSFORMERS AND HOME WIRING

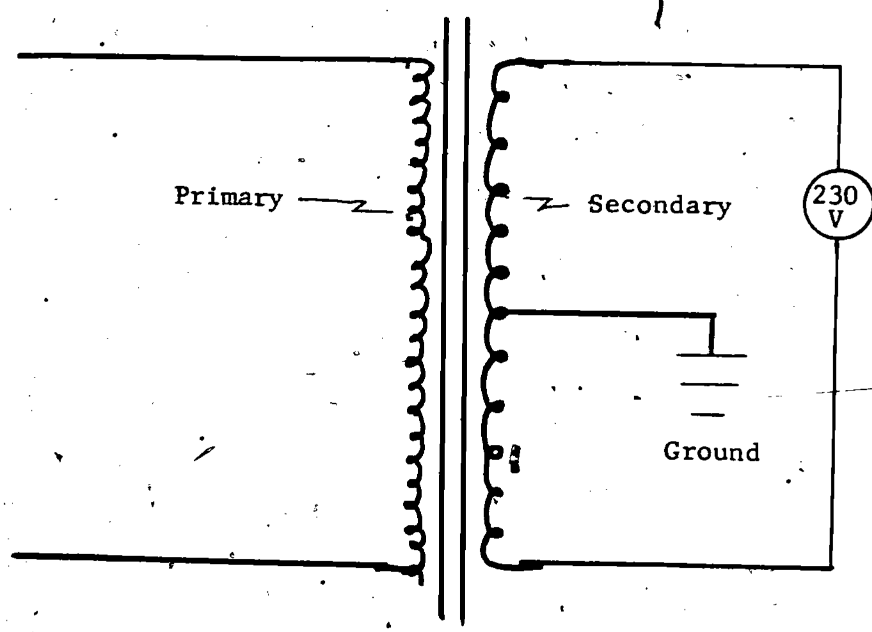
Electric power (energy) is distributed from the power generating station to the areas where the energy is going to be used, at voltage levels far higher than those at which it can be used by the residential customer. The distribution voltages are from 13,000 up to as high as 130,000 volts; the residential consumer voltages are from 120 to 220 volts. The reason for high voltages for power distribution is that it is more efficient than lower voltages. The power transmitted from one point to the other may be calculated (in its most simplistic form) as the product of current, I, times voltage, V. Can you see that as the voltage is increased, the required current decreases for a given rate of power transmission? If the current decreases, smaller conductors may be used for power transmission at higher voltages. And high-voltage transmission has less line losses of energy than low-voltage transmission. To illustrate this, consider the formula for Ohm's Law ($V = IR$); substitute IR for V in the over-simplified power formula, $P = IV$, and one get $P = I^2R$. From this relationship, can you infer that line losses of energy would increase as the square* of the current? Therefore, keeping the transmission voltage high, and the current low, minimizes line energy losses.

* Doubling the current results in four times as much energy loss; tripling the current results in nine times as much energy loss.

Transformers consist of a pair of wire coils wound around an iron core; such windings can step up the AC voltage or step down the AC voltage. Further, current relates inversely to this voltage; if voltage is stepped up, current goes down (and vice versa)! Physics-wise, a changing magnetic field is set up by current going through the primary coil; this changed field <u>induces</u> (sets up) a voltage in the secondary coil. The ratio of the voltage in the secondary coil to the voltage in the primary coil is the same as the ratio of the number of turns of wire in the secondary coil to the number to the number of turns of wire in the primary coil:

$$\frac{V(\text{primary})}{V(\text{secondary})} = \frac{\text{No. turns (primary)}}{\text{No. turns (secondary)}}$$

Fig. 4-1 is a schematic of a transformer of the type usually used in residential areas. The voltage across the two outside leads of the secondary side is 230 v, and the center tap is grounded or connected to the earth so that its potential is zero. On any given half cycle, one outside lead of the secondary is at a potential of +115 v and the other is at a potential of -115 v.

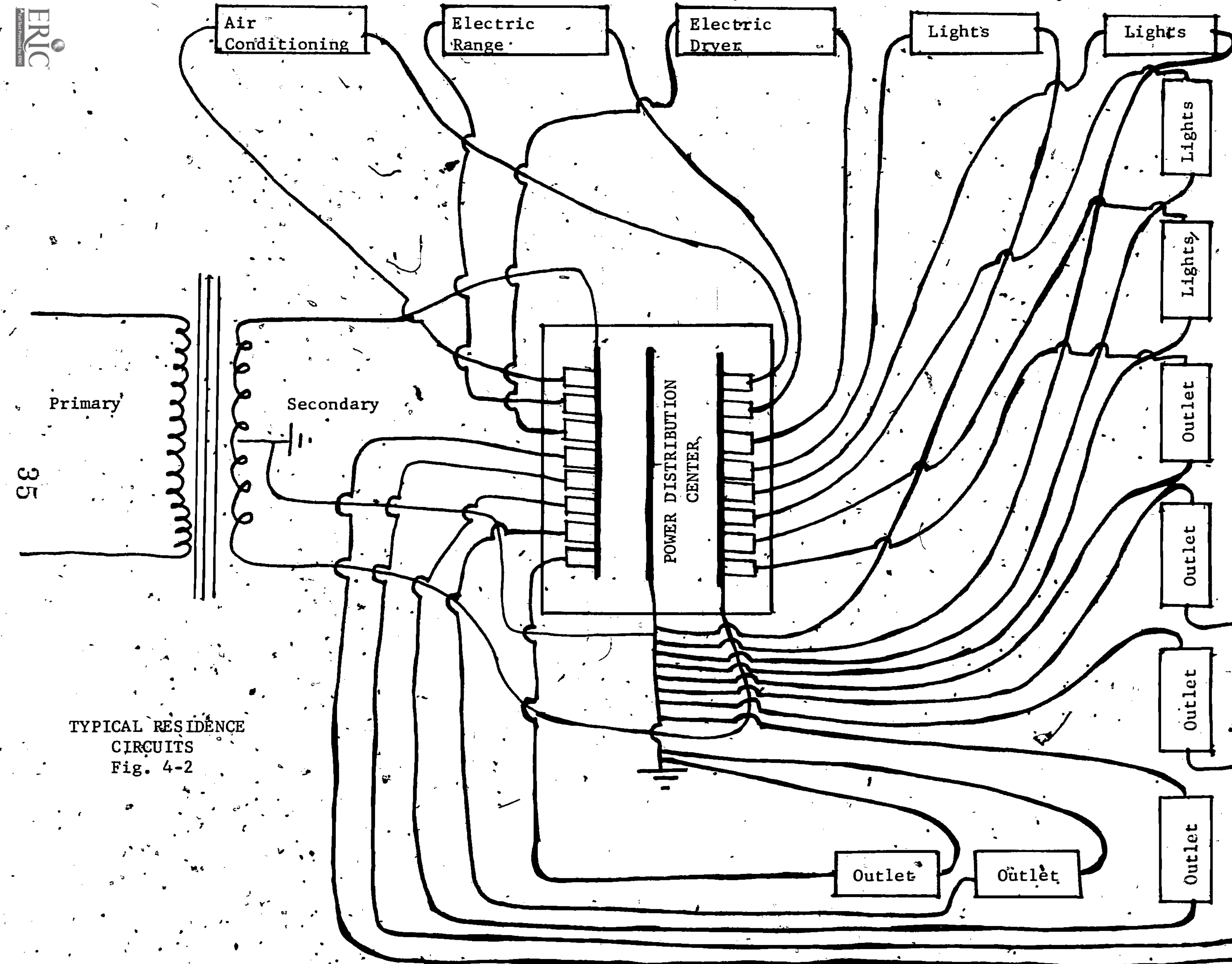


TRANSFORMER
Fig. 4-1

All three of these leads are run from a pole (or underground site) into the meter box of the residence. The outside leads furnish a potential for 220-volt devices (electric stoves, air conditioners, dryers, etc.) and the center tap gives a potential of 115 volts for small appliances and lights.

The reason that many large appliances are usually designed to operate at higher voltage is the same as the reason for using high voltage for power line transmission; higher voltage and lower currents result in high efficiencies. Fig. 4-2 shows typical wiring for a residence. There are a large number of circuits coming from the power distribution center; this center is the <u>fuse box</u> or <u>circuit-breaker box</u>. You might wonder why so many circuits exist if there are only two circuits coming into the center. One could wire a house with only two circuits, having all devices connected directly to the two incoming circuits from the transformer. But, in order to do this, one would sacrifice safety, in terms of electrical shock, and would increase the chance of fire (should one of the appliances short out.)

Each separate circuit has its own fuse or circuit breaker. In the event that excessive current is drawn by that circuit, the fuse will burn out or the circuit breaker will automatically open ("break" current to that circuit.) If there were only one or two circuits, the protective device would have to permit so large a current to pass before activating that relatively little protection would exist.



TYPICAL RESIDENCE CIRCUITS
Fig. 4-2

The following three exercises are exercises in basic electric circuits and in the use of the transformer. Since we cannot supply you with a house to wire at the present time, these will at least let you see how a simple circuit is wired. The parallel circuits are the ones that are most related to the wiring of a house.

EXERCISE I: SERIES CIRCUITS

In this exercise you will study electrical current through elements wired in series, and be introduced to the use of Ohm's and Kirchoff's Laws.

In order to have current in a circuit, it is necessary that the circuit be completed or closed. In other words, there must be a continuous, unbroken conductor between the two terminals of the source of electromotive force (voltage); a battery or a generator would be an example of such a source. Voltage, current and resistance are three of the terms that one encounters when working with circuits. These are defined below:

Voltage (symbol E or V): electromotive force; the difference in electrical potential between two points; electrical "pressure"; a measure of the work necessary to move charges between two points in an electric field. The unit of voltage measure is the volt.

Current (symbol I): the rate of transfer ("flow") of electric charge carriers. A current measure is the ampere. One ampere is equal to a transfer of one coulomb per second.

Resistance (symbol R): the measure of opposition to the transfer ("flow") of electrons. The unit of resistance measure is the <u>ohm</u>.

In a circuit, the resistance is a measure of opposition to current. From experimental results, it is evident that the higher the resistance, the lower the current, and vice versa. Can you relate this discussion to the experimental evidence that the electromotive force (potential <u>drop</u>) in a circuit can be expressed mathematically as the product of the current value and the resistance value? In mathematical form

$$V \text{ (voltage)} = I \text{ (current)} \times R \text{ (resistance)}$$

OR

$$V \text{ (volts)} = I \text{ (amps)} \times R \text{ (ohms)}$$

From this equation, you can see that, if given any two of these DC circuit factors, it is easy to calculate the third. This statement, $V = IR$, is known as Ohm's Law.

Consider that when two or more resistance devices (<u>resistors</u>) are connected in a circuit, it is necessary to calculate their collective electrical resistance in order to calculate the current in the circuit. A series arrangement of resistors can be likened to connecting lengths of water pipe together; there is only a single path for water to flow and it flows in a series from one pipe section to the next, to the next, etc., in a chain-like fashion. When resistors are connected in <u>series</u>, their resistances add arithmetically in order to find their total resistance effect in the circuit; let R_T be the total resistance (<u>effective resistance</u>, or <u>equivalent resistance</u>) in the circuit, and R_1, R_2, R_3, etc. be the individual resistors, then:

$$R_T = R_1 + R_2 + R_3 + \ldots R_n$$

Since all the resistors are connected in series, and there is only <u>one</u> path that the current can take, the current past any <u>point</u> along the series circuit will be the same as the current past any other point.

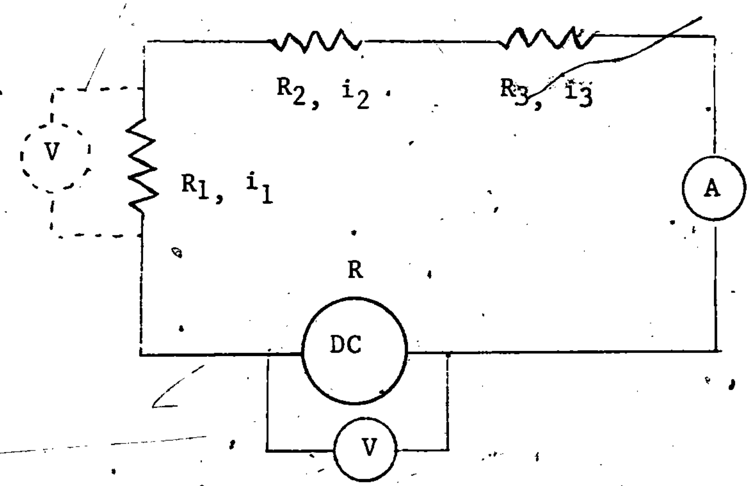
MATERIALS:

1) Low voltage DC power supply
2) Voltmeter
3) Ammeter
4) 3 resistors (of known ohm values and of low ohm values)
5) Connecting wires

INSTRUCTIONS:

1) Set up the apparatus as shown in Fig. 4-3. Make the wires connecting the circuit elements as short as possible (so that the wire's resistance will not appreciably affect the results of your work.)

2) Have your instructor OK your circuit. Then turn the power on and record the source voltmeter reading and the circuit ammeter reading. Since there is only one path for the current, the current (i_1 at R_1, i_2 at R_2, i_3 at R_3) through each resistor is the same; that is, $I = i_1 = i_2 = i_3$.



SERIES RESISTOR CIRCUIT
Fig. 4-3

3) Disconnect the voltmeter and connect it across the resistor R_1. Record the voltage drop (V_1) across this resistor and record the circuit ammeter reading.

4) In the same manner as step 3 above, determine the voltage drops (V_2 and V_3) across the other two resistors. Again, record the respective ammeter readings.

5) Using Ohm's Law, calculate R_1, R_2, and R_3, and complete the data table below (draw a facsimile of this table in your notebook; do not write in this minicourse). Compare the calculated resistance values with the known resistance values.

6) Complete the blanks in the data table.

	Source	R_1	R_2	R_3	Total
Voltage drop					
Current Through					
Resistance (Calculated)					

Kirchoff's Law for voltage may be stated as follows: The sum of the voltage drops around a direct current series circuit will equal the voltage of the source. Verify this law, using your experimental results.

QUESTIONS:

1) What are some possible sources of error in this investigation? List and explain.

2) What would be the effect on the accuracy in this experiment if a low resistance voltmeter was used?

3) Ask your teacher to assign some related circuit problems from a physics text.

We know that this has been a somewhat laborious exercise; and, frankly, the next one is equally long and laborious. Keep in mind, however, that the purpose of these two exercises is to familiarize you with the two types of electric circuits that you will encounter in general electrical wiring.

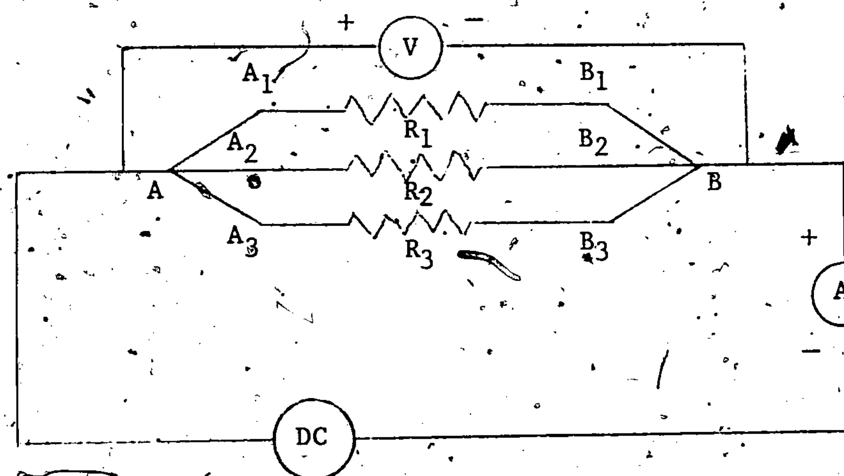
EXERCISE II: PARALLEL CIRCUITS

The parallel circuit is used in the various electrical circuits in the home. Home currents are AC, and although AC circuit resistance values are calculated somewhat differently than DC circuit values, the concept of parallel is the same. When resistors are connected in parallel, they act somewhat independently of each other in terms of current. However, each resistor experiences the same applied voltage. In parallel, the current through each resistor is determined by the individual resistance of each and by the common applied voltage. Again, to calculate circuit current, it is necessary to know the collective electrical resistance. This collective resistance can be found by adding the reciprocal of each resistor in parallel:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_n}.$$

MATERIALS:

The same as for Exercise I, except that an ohmmeter is also needed.



PARALLEL RESISTORS CIRCUIT
Fig. 4-4

INSTRUCTIONS:

1) Set up the apparatus as shown in the diagram. Record the voltmeter reading, V, and the ammeter reading, A. The reading of the voltmeter is the voltage drop in the external circuit (neglecting the resistance of the connecting wire and the ammeter). But, since the voltmeter is connected across the collective resistance due to R_1, R_2, and R_3, it is obvious that equal voltage exists for all three resistors. That is, $V = V_1 = V_2 = V_3$.

2) Remove the ammeter and connect it between points B and B_1. Make tables in your notebook similar to those on page 43. Record the reading, i_1.

3) Repeat #2, above, with the ammeter connected between points B and B_2, and then between points B and B_3. Record the values of i_2 and i_3.

4) Calculate R_1, R_2, R_3, and R_T by Ohm's Law.

5) Calculate R_T by the reciprocal method. By Ohm's Law, the total (the equivalent) resistance is equal to the total voltage drop divided by the total current; that is, $R_T = \frac{V_T}{I_T}$ but $I_T = i_1 + i_2 + i_3$.

$$\text{Therefore, } R_T = \frac{V_T}{i_1 + i_2 + i_3}$$

$$i_1 = \frac{V_1}{R_2} \; ; \; i_2 = \frac{V_2}{R_2} \; ; \text{ and } i_3 = \frac{V_3}{R_3}$$

$$\text{so } R_T = \frac{V}{\frac{V_1}{R_1} + \frac{V_1}{R_2} + \frac{V_3}{R_3}}$$

Since $V = V_1 = V_2 = V_3$, the formula may be written:

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

A more convenient form of this equation is obtained by <u>inverting</u> both sides of the equation. The equation then reads $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots \frac{1}{R_n}$.

If only two resistances are involved, the equation is $R_T = \frac{R_1 R_2}{R_1 + R_2}$.

6) Open the switch and determine the total resistance between points A and B, and the resistance of each individual resistor using the ohmmeter.

DATA:

V_T = ____________ I_T = ____________

Resistor Number	Voltage Drop	Current	Resistance by Ohm's Law	Resistance (Ohmmeter)	Total Resistance (reciprocal formula)
#1	$V_1=$	$i_1=$	$R_1=$	$R_1=$	
#2	$V_2=$	$i_2=$	$R_2=$	$R_2=$	
#3	$V_3=$	$i_3=$	$R_3=$	$R_3=$	
Total	$V_T=$	$I_T=$	$R_T=$	$R_T=$	

Kirchoff's Law for currents may be stated as follows: The sum of the currents flowing toward any point in a circuit junction (network) is equal to the sum of the currents flowing away from the same point.

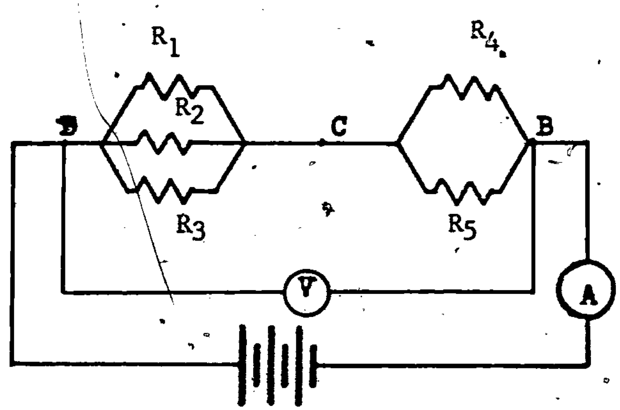
Verify the Kirchoff's Law for currents as follows:

Assume a current direction from Point B to Point A, in Fig. 3-4. Fill in the blanks below:	
Current flowing toward Point B (original ammeter reading).	Ohms
Current flowing away from Point B (ammeter readings for $i_1 + i_2 + i_3$).	Ohms

QUESTIONS:

1) In your notebook, list some possible sources of error in this investigation.

2) In the circuit below; $R_1 = 2$; $R_2 = 4$; $R_3 = 4$; $R_4 = 2$; $R_5 = 3$; where R's are in ohms and the voltmeter reads 11 volts. Find the total (equivalent) resistance between B and C; C and D; and B and D. Find the total current, I, and the current through each resistor. Verify Kirchoff's Current Law by comparing $i_4 = i_5$ with $i_1 + i_2 + i_3$.



Resistance Between:

B & C ______

C & D ______

B & D ______

I_T ______

i_1 ______

i_2 ______

i_3 ______

i_4 ______

i_5 ______

3) What advantages do parallel circuits provide for the wiring of a house? List a few of these.

4) Ask your teacher to assign some simple problems related to this study of parallel circuits.

EXERCISE 3: TRANSFORMER

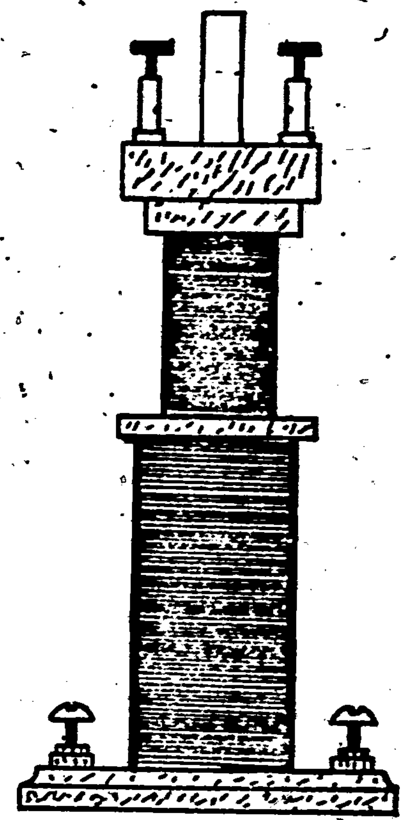
As was previously mentioned, the purpose of the transformer is to step voltage or current up or down. You will be able to see this demonstrated as you do this exercise. You will also see a fundamental phenomenon which is the basis of many electric/electronic devices; namely, a changing magnetic field causes an electric current in a coil. And the corollary is that a coil moving across a magnetic field will experience a current.

MATERIALS:

1) Primary-secondary coil arrangement
2) Low voltage AC source
3) Iron core for coils
4) AC voltmeter
5) Galvanometer with zero at center scale
6) Bar magnet
7) Connecting wires

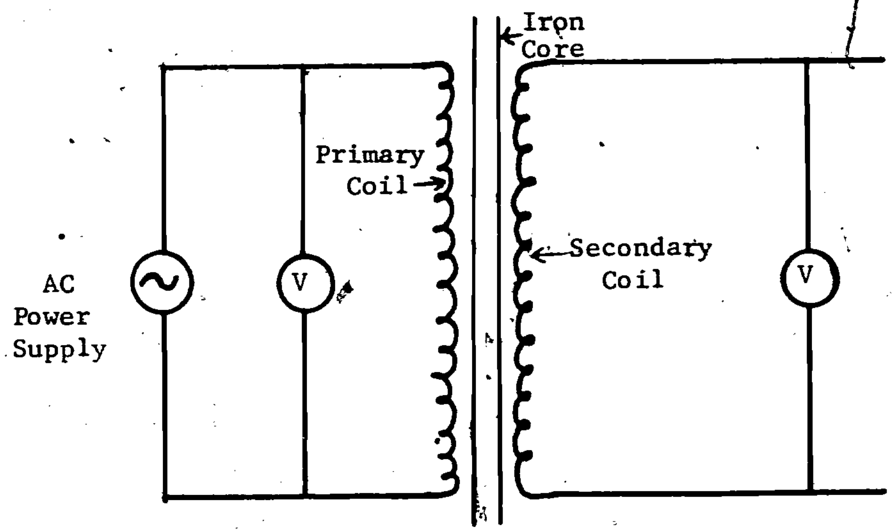
INSTRUCTIONS:

1) Connect the terminals of the outside coil to the galvanometer.
2) Slowly lower the magnet into the coil; then remove it. Repeat this process using different speeds. Record in your notebook the results, and offer an explanation for them.



TRANSFORMER
Fig. 4-5

3) Connect the circuit as shown in Fig. 4-6, below.



THE TRANSFORMER
Fig. 4-6

4) Record the voltages on both the primary and the secondary coils.

5) Ask your instructor for the number of turns of wire on the primary and the secondary coils.

6) Since the ratio of the voltage of the primary coil to the voltage of the secondary is the same as the turns ratio of the two coils, use this to check your meter readings. Calculate the percent difference between the meter readings and the theoretical values derived from the turns ratio. Show your calculations in your notebook.

RESOURCE PACKAGE 4-2

HOME ELECTRICAL REPAIR

From January to May, 1974, 527 fires were reported to the Dallas Fire Department that were of electrical origin. Almost without exception, these resulted from defective wiring of a house, an appliance and/or overloaded circuits. Major electrical repairs or rewiring of a home should be undertaken only by a qualified electrician; however, there are things a home-owner can do to make simple repairs. A home-owner can also recognize a source of potential electrical problems or hazards.

Included as part of this Resource Package are reprints of three publications of the Texas A & M College System and the United States Department of Agriculture. Read all three of these and complete the following:

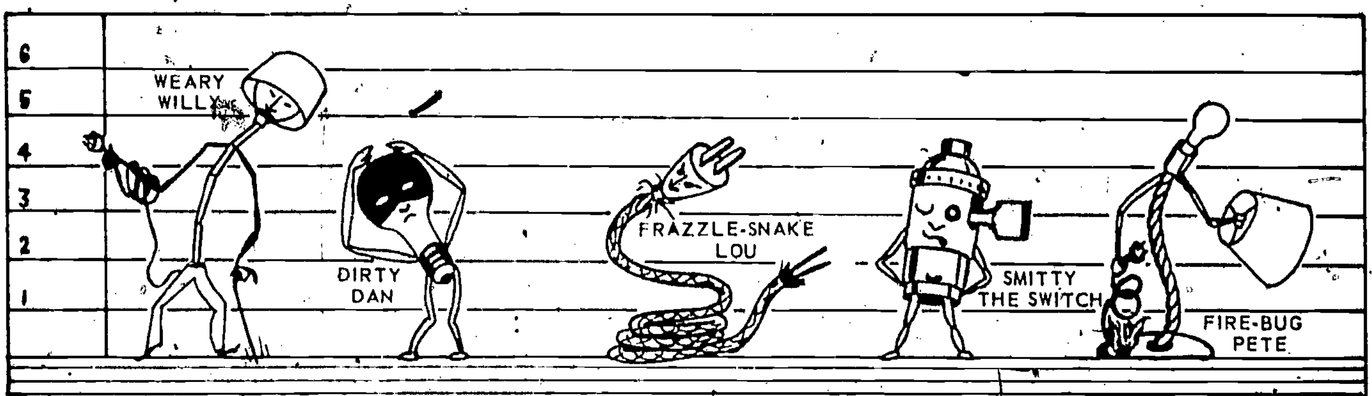
1) Find a lamp that is no longer functioning properly and repair it. Do this under the close supervision of your instructor.

2) In your notebook, make a checklist of things that homeowners should know and/or should perform regularly to minimize electrical problems or hazards.

3) In your notebook, write answers to the seven questions of the section, "What Did You Learn?" in the publication, Rewire A Lamp.

L-471

REWIRE A LAMP - BE A LAMP DETECTIVE



The Line-Up of Lamp Suspects

One of the duties of a law officer is to prevent crime. It's that way with the lamp detective. You can become one. In the average home there are lamps about to commit the crime of shocking people, starting fires, and stealing electricity. Some are refusing to do their job well and some are no-goods, sitting in closets or attics, doing nothing. You can put these lamps to working again safely and well. Become the lamp expert in your family.

What's In A Lamp?

A lamp gives light for comfortable and convenient use in the home. It consists normally of a stand, switch, cord, lampshade holder, and shade. Some lamps have diffusing bowls which reduce glare and shadows.

The most common fault found in an old lamp is in the cord, but sometimes the switch or the wiring in the lamp is bad. Look over all the lamps in your home and find the ones needing to be fixed.

WHAT TO DO: Rewire A Lamp

Somewhere around your house you can probably find a lamp that is no longer used or needs repairing. You can make it useful again and at the same time learn how to wire a lamp.

Materials Needed:

Tools: Pocket knife, small or medium screwdriver, and pliers (electrician type is best).

New Lamp Cord: For each lamp to be rewired, you'll need 6 feet of cord plus the length of wire within the lamp stand. Lamp cord wire comes in two sizes, No. 18 and No. 16 AWG (American Wire Gauge). No. 18 is smaller than No. 16, but is adequate for most lamps. Cords are made with surface coverings of several different materials: braided cotton, rayon or silk, and molded rubber or plastic. Braided cord is decorative, but rubber or plastic is easier to work with and is usually more desirable.

Switch: If the switch is bad, get a new one. Socket switches are made with push-through, turn-knob, or pull-chain controls. The pull-chain type is seldom used on modern table or floor lamps. Your lamp may have a separate push-switch in the base. In this case, get the same kind for replacement. Some switches are "3-circuit" switches for use with high, medium, and low-light bulbs.

Plug: Plugs are made of various materials, mostly hard rubber or molded plastic. Some have a shank or handle for better grasping. This type is more desirable. The plug on the old cord may be good, and if so, may be used on the new cord.

How To Do It:

1. If the plug on the old cord is good and you plan to use it, remove it from the old cord.

2. Measure and cut a new lamp cord equal to the length of the cord within the lamp, plus 6 feet.

3. Pass one end of the new cord through the center of the plug. Strip 2 inches of the fabric insulation off cord, or in case of a rubber cord, split cord back two inches. Be sure no bare wire shows in long split section (Figure 1).

4. Use knife to strip insulation off wire for 3/4" on end of each cord. Be careful. Don't cut yourself. Don't cut wires. Use a light touch, slope the knifeblade and slice with knife edge away from you (Figure 1).

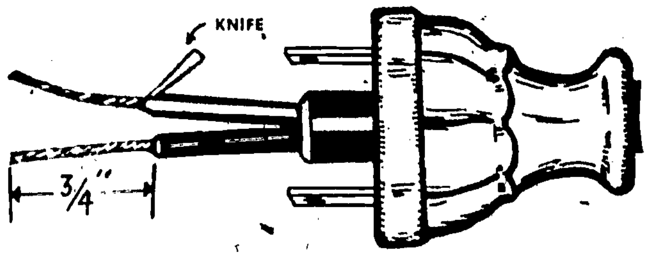


Figure 1 (Ready to Wire Plug)

5. Twist exposed strands of each wire tightly to make a good conductor, and place each conductor around its proper terminal in the direction in which the screw tightens (Figure 2).

6. Tighten screws on terminal posts. Pull cord until slack is out. Lay aside until ready to attach to lamp.

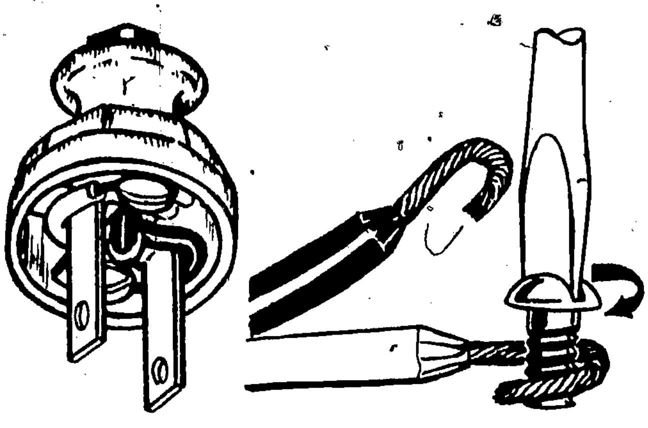


Figure 2 (Attaching Cord to Plug)

7. Remove lamp shade, shade-holder, bulb, and diffusing bowl, if there is one.

8. Separate the metal shell of socket from its cap by pressing on shell at place marked "press," and pull socket from cap.

9. Pull on socket body to get some slack in lamp cord. Loosen screws and detach cord. Pull cord out through base of lamp. You can splice new cord to the old one and use the latter to "string" the new wire.

10. Pass the new cord up through the lamp base and socket cap, tie a simple half-hitch knot in the cord to prevent strain on the terminals, and attach wires to the terminals on the socket (Figure 3). If there is likely to be any strain on cord, use an Underwriters' knot. Twist strands and attach wire in direction in which screw tightens.

11. Pull slack out of cord in lamp so that socket rests in socket cap, replace shell and reconnect cap. Be sure the fiber insulator is in the shell. You'll feel or hear a click when the notches in shell are locked to the projections in the cap.

12. Replace bulb, inspect carefully, and test. (In floor lamps where the cord runs through the center post and out under the base, the cord will last longer if it is fastened with tape so it doesn't rub edge of lamp base when lamp is moved.)

13. If the lamp has a porcelain socket, simply disconnect the wires at the terminals, remove the old wire and connect the new one.

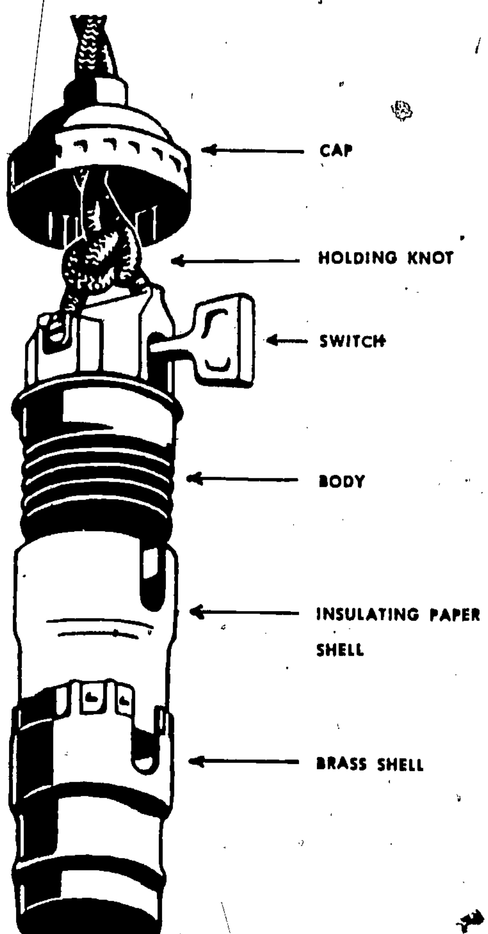


Figure 3 (Socket and Switch Assembly)

What Did You Learn?

Underline correct answers then discuss in the group. (There may be more than one correct answer.)

1. The part of the lamp that usually wears out first is (the socket) (the cord) (the plug).

2. Lamps that waste electricity are those which have (bad wiring) (frayed cords) (dirty shades or bulb).

3. To unplug a lamp you should grasp (cord) (plug) firmly and pull.

4. Wire in lamp cord usually comes in sizes 16 or 18. Size 16 is the smaller (true) (false).

5. In fastening wire around a terminal post it should go around in a (clockwise) (counter-clockwise) direction.

6. When the switch on a lamp is turned off, the electricity only goes as far as (the wall plug) (the switch).

7. An Underwriters' knot should be used (only when there is room for it in the plug) (whenever there is likely to be strain on the cord, even if you have to replace the plug with a larger one).

SUGGESTED DEMONSTRATIONS

Show how to inspect a lamp and its cord. You might tie tags on the cord and lamp at points of danger or failure - at the plug, wear points next to lamp base, bad sockets.

Demonstrate the process of repairing a lamp cord, socket and plug.

Make a board display of the parts of the lamp socket showing cord attached.

Make a display of the types of lamp cords and plugs in common use.

Using two lamps, one with clean bulb and shade, the other dusty, show how the former gives more light.

For More Information

Lamps have an interesting history. Look it up in your local library. Ask someone from your power supplier or electric dealer to talk to the club about the different kinds of lamps. Your leader has or can get additional information on lamps, if you wish.

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RESOURCE PACKAGE 4-3

CHECKING AN ELECTRICAL CIRCUIT LOAD

Is your house wiring adequate or it is unsafe and a potential fire hazard? How does one know when a home is safe from fires of electrical origin? One might think that a fuse will blow or a circuit breaker will trip if there is a problem in a circuit. This should be the case, if the electrical installation has been done properly.

Let's consider what under-size wire can do? A wire has electrical resistance, and this resistance is related to the material itself, is directly proportional to the length of the wire and is inversely proportional to the cross sectional area of the wire. This means that as the conductor gets longer, the resistance increases; and as the cross sectional area of the conductor gets smaller, the resistance also increases. How can one determine that the wire size is sufficiently large to accomodate safely the electrical load.

Consider this example: 14-gauge copper wire has a resistance of 0.008258 ohms per meter. If you need to run this wire for a distance of 100 meters and pass 15 amps current through it you may be in trouble. Let's see why: the power requirement (the rate of electrical energy used along the conductor) may be calculated by the relationship:

$$\dot{P} = I^2R.$$

Since the resistance is given as 0.008258 ohms/meter, and since the length is 100 meters, the total resistance is (0.008258 ohms/meter) times (100 meters). Therefore,

$$P = I^2 R$$
$$= (15\ \text{amps})^2\ (0.008258\ \text{ohms/meter})\ (100\ \text{meters})$$
$$= (225)\ (0.008258)\ (100)$$
$$= 185.8\ \text{watts}$$

Because there are approximately 3 BTU's of heat energy to the watt, there will be about 557 BTU's of heat given off by this conducting wire in one hour of operation. The wire will get hot, but will not constitute a hazard because this heat energy is evenly spread out over the entire 100 meters of conductor. However, there is a problem associated with this circuit; namely, at the end of the conductor, where the appliance is to be operated, there will be a relatively lower and unsafe voltage for many kinds of appliances.

To calculate the approximate voltage drop along this conductor, one can use the relationship, $P = I\ V$ and solve for V. Then,

$$V = P/I$$
$$= 185.8\ \text{watts}/15\ \text{amps}$$
$$= 12.4\ \text{volts}$$

This shows that the voltage will be 12.4 volts lower at the end of the circuit; such a drop can cause damage (burn-out) in certain electric motors. One should design a circuit system so as to never have

more than 5 volts drop, in order to assure satisfactory operation of appliances.

Many homes are wired with aluminum wire, instead of copper. While aluminum is a satisfactory conductor, it has a higher resistance than copper. It turns out that the current capacity of aluminum wire is only 84% of that for the same size copper wire, because of aluminum's higher electrical resistance.

Obtain a copy of the Handbook of Chemistry and Physics published by the Chemical Rubber Company, and turn to the tables showing the electrical resistance properties of copper wire. Notice that this Handbook contains information on the resistance of various sizes of different kinds of conductor materials and the safe current-carrying capacities of these various sizes of wire.

EXERCISE 1: SPECIFIC RESISTANCE

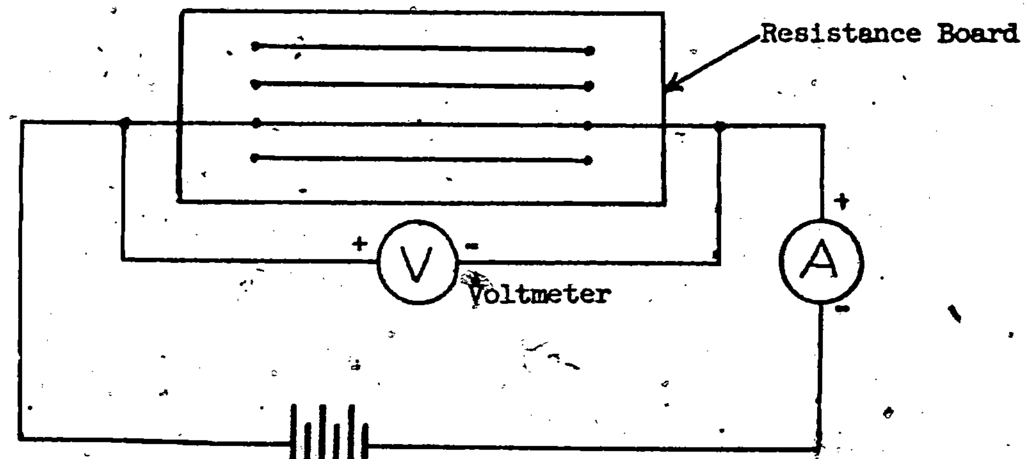
MATERIALS:

1) Resistance board, with lengths of four different kinds of wire
2) DC voltmeter
3) DC ammeter
4) Connecting wires
5) Low voltage DC power source

INSTRUCTIONS:

1) Set up the apparatus as shown in Figure 4-7 using any one of the wires on the resistance board in the circuit.

2) Close the switch just long enough to read the voltmeter and ammeter. Record the readings in your notebook; use a table such as the one on the next page.



MEASURING SPECIFIC RESISTANCE
Fig. 4-7

3) Repeat the above procedure for each of the other three wires.

4) Use Ohm's Law to calculate the approximate resistance of each of the wires. Do the calculations in your notebook.

5) Next, show the calculations for the specific resistance (resistivity) of each of the wires. Use the formula:

$$R = \rho L/A$$

where: R is the total resistance of the wire

ρ (rho) is the resistivity in ohms per centimeter

L is the length in centimeters

A is the cross sectional area, in square centimeters.

6) Use the Handbook of Chemistry and Physics to find the accepted value of rho. Calculate the per cent difference between the accepted value and the value found in procedure number 5, above. Do this calculation in your notebook for each wire.

Gauge Number and Kind of Wire	Volts	Amps	Ohms	ρ (rho) Calculated Value	ρ (rho) Accepted Value	Per Cent Difference

QUESTIONS: (Record the answers in your notebook):

1) Of the wires you tested, which material had the lowest resistivity?

2) How does cross sectional area affect the resistance of a conductor?

3) How does length affect the resistance of a conductor?

EXERCISE 2: CHECKING WIRE SIZE

During this activity, you are to determine whether the electrical wiring in a home is appropriately sized. The simplest way to do this is to go to where a house is being constructed and the electrical wiring has been installed, but the inside walls have not yet been put up and the wiring is still exposed. In a finished house it is more difficult to determine the wire size and the actual length of the conductors; however, begin at the circuit breaker (or fuse box) and list the amperage rating on each of the circuit breakers or fuses. This rating is the maximum number of amps that can be carried by that particular circuit before the breaker will trip or the fuse will blow. Next, determine the wire size and estimate the length of wire for each circuit.* (Remember that each circuit will consist of a length of conductor which is twice the distance from the fuse box (breaker box) to the appliance (outlet), so you must multiply the measured distance to the outlet by two.) Use the criteria in the introductory section of this minicourse to determine whether the wiring is adequate.

Construct a table in your notes to display this information.

* Another alternative is to ask your instructor for the electrical wiring plans for a structure and get these data from the wiring diagrams.

RESOURCE PACKAGE 5-1

HOW TO BUY AN APPLIANCE

It seems hard to imagine that at the end of World War II, most U. S. homes had from fewer than three electrical appliances. And just prior to World War II (in 1944), the average homeowner could purchase a refrigerator, an electric fan, perhaps an electric range (that did not work very well), a wringer type washer, and perhaps as many as three small kinds of kitchen appliances. All of these were still novelty items and were relatively expensive. For example, it took about a month's salary for the average worker to buy a refrigerator with freezer space only for ice trays, and with a food storage space of about eight cubic feet.

Appliances are some of the few things that have not gone up in price as they have been improved and as our economy has become inflated. The prices of appliances have remained about constant since the time they were placed on the market during the 1930's, and their quality and usefulness has been vastly improved.

Today, many U. S. citizens use their appliances as if they were "throw away" items; and certainly many appliances are currently designed with the idea that they will be thrown away rather than repaired. This kind of design wastes much material resources needlessly and results ultimately in higher costs to the consumer. If one approaches the purchase of an appliance wisely, it is possible to select one that should give satisfactory service for years and require only relatively minor repairs.

When you purchase an appliance, you should consider the following:

1) cost
2) availability of service
3) efficiency of operation
4) durability
5) reputation of the dealer

The cost of a given appliance make and model may vary widely within a given area. This price range frequently has to do with the type of dealer selling the appliance. If the item is sold through a discount store, where purchases are made in large volume and no service department is made available to the customer, the price will usually be lowest. This, however, may or may not be the best purchase if a buyer must depend on factory service branches for service. Before purchase, it is best to investiage the places where one can get satisfactory maintenance and repairs on the appliance under consideration.

Suppose you consider buying from a small volume business. The appliance price will probably be the highest, because the merchant has had to purchase the inventory (goods for sale) in small quantities. However, the smaller business operator knows that to stay in business, the customer must be furnished something that cannot be obtained from the competitive discount store; frequently this means that the smaller operator is prepared to take care of whatever service problems may arise, or have them taken care of for you. If a problem arises that cannot be taken care of promptly, the smaller dealer may even be in a position to lend an item until repairs are completed.

Before the beginning of the "energy crunch," Americans gave little consideration to the operating cost of appliances. Electrical energy was so inexpensive that one did not need to seriously consider its cost. But now cost of appliance operation (efficiency) is becoming increasingly important to the consumer. If you had a one-horsepower electric motor that was 100 per cent efficient, it would require 746 watts to operate it. Of course, there is no such thing as a 100 per cent efficient motor, but you might be surprised how close to this some manufacturers can get. Today electric motors can be purchased that require from about 820 watts (91% efficient) to 1,500 watts (50% efficient) to deliver one horsepower. The more efficient motors usually cost more to purchase, but will usually be worth many times the initial cost difference in savings in power consumption in the long run.

Probably the largest consumer of electric power in the home is the air-conditioning system. An efficiency rating for these systems (called <u>coefficient of performance</u>) is usually available from the dealer, or such a rating can be readily determined by the wise consumer. Coefficient of performance can be calculated by dividing the cooling capacity (in BTU per hour) by the power consumption (in watts). This performance number can range from about 5 to 10 for various models of the same system! Can you see that an air-conditioner with a coefficient of performance of 10 would require <u>half</u> the power to operate that one with a performance coefficient of 5 would require?

<u>Consumer's Report</u> is an example of periodical publications dedicated to the evaluation of consumer items and presenting consumers with a good idea of which items are best values. The Report publishes evaluations of items for cost, durability, safety, and efficiency; these reports are usually very reliable.

INSTRUCTIONS:

1) Choose an appliance that you might wish to purchase for your home.

2) Check with Consumer's Report, or equivalent publication, to determine which brand or brands you should consider purchasing.

3) Compare the selling price and type of customer service offered by at least two dealers for this appliance.

4) Make a chart of at least two different brands of this appliance; include efficiency, price at different dealers, customer service offered by different dealers, safety features, and projected durability.

5) From your data, determine which is the best purchase for you.

RESOURCE PACKAGE 6-1

TROUBLESHOOTING

In today's society if something doesn't work, we throw it away and buy a new one. This process is basically wasteful and must mostly be discontinued in the future. On the other hand, if an electric appliance of the small, kitchen variety is taken to a repair shop to be repaired, the cost may well equal or exceed the price for which a new replacement can be purchased at the local discount store. Therefore, it makes economical sense to throw it away and to buy a new one. However, the appliance's problem might be one that you can repair in a short time, and at little or no expense.

In your home you probably have some electrical appliance that no longer functions, and it is there simply because no one has bothered to throw it away. If this is the case, bring it to school to use with this Resource Package. (If you do not have such a sick appliance, check with your friends until you find something like an electric percolator, toaster, waffle iron or other small appliance that doesn't work and that you can take apart and study.) If you get your sick appliance from a friend, make sure that s/he* understands that s/he may not get it back in usable condition!

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* she/he

MATERIALS:

1) screwdriver
2) long-nose pliers
3) diagonal cutters
4) soldering tool
5) ohmmeter, or some device to check circuit continuity

INSTRUCTIONS:

PROCEDURE	REASON FOR STEP IN PROCEDURE
1. Plug in the appliance, and turn it on so that you can observe its function or dis-function. Be prepared to QUICKLY unplug it!!	This gives you the opportunity to observe what the appliance either will or will not do. (Be sure to unplug it immediately after observation.)
2. Check the connections of the wires to the terminals inside the electrical outlet plug.	A break anywhere in the circuit will cause the power not to get to the appliance; it will be just like having a switch open.
3. Caution - 110 v. AC CAN KILL - Be Careful! With the cord unplugged, if the power cord is readily removable, check the continuity	The power cord on the appliance has to take a great deal of abuse simply because the appliance is probably moved a great deal. After

through each lead of the wire with the ohmmeter, or other testing device.	excessive bending, metal will often break and open the circuit.
4. While unplugged, if the cord is not readily removable, disassemble enough of the appliance to examine the terminals where the power cord is connected. Disconnect the power cord and check its continuity, as you were instructed in Step 3.	Same as the reason in Step #3.
5. With the off-on switch in the <u>on</u> position and the appliance NOT plugged into the power source, check the resistance across the leads of the plug. Since the appliance is probably designed to operate on 115 volts, and the expected current draw can be readily determined from information printed on the appliance, you can calculate what the resistance of the appliance should be.	This will tell you if a circuit is open in the appliance itself. If the reading of the ohmmeter stays on the <u>infinite</u> position, you know that something is not allowing current to pass through the appliance, and the component that is causing this is the offending member. However, if the appliance is a motor, the resistance will normally appear lower than the calculated value.

6. Disassemble the appliance enough that you can get to the electrical components of the appliance. (Take care to note just how each part is taken off, so that you will have minimum difficulty in the reassembly process; do not hesitate to tag pieces or to make drawings which will help reassembly.)

In order to check a component you must be able to get to it. Also, one can obviously reassemble a device more easily if one knows how it was taken apart.

7. With the ohmmeter, check each part of the circuit to determine which part is open.

This should identify the problem.

8. Check with a service man or parts store on the cost of the part.
9. Repair or replace defective part.
10. Check with your teacher to make sure that you have not created an electrical hazard in the repair process!
11. Reassemble the appliance and check its function, as in procedure #1.

RESOURCE PACKAGE 7-1

KIT BUILDING (OPTIONAL)

You have now completed all the required work in this minicourse. The skills that you have learned should be of considerable benefit to you in the future. You probably already know that kits may be purchased to build electronic devices ranging from simple power supplies costing under $10.00 to color television sets costing more than $500.00. If there is something that you would like to have for yourself, why don't you buy yourself a kit and assemble it as part of this course? Please do not start with a color television set. Consult with your teacher about what you would like to build (select something that you can accomplish within a few weeks); buy it in kit form; and assemble it. Be certain that you obtain your kit from a reputable company, so that if there are any defects in any of the parts you will have no difficulty in getting them replaced.

ELECTRONICS AS A HOBBY

SELF-TEST

1) Demonstrate a good solder connection.

2) Draw a schematic of the following:

   a. half-wave vacuum tube power supply
   b. full-wave vacuum tube power supply
   c. half-wave solid state power supply
   d. full-wave solid state power supply with a π-filter

3) Explain how a house is wired, beginning with the high voltage line from the transformer. Include a diagram.

4) How is the speed varied on a DC motor?

5) Give a step-by-step procedure for troubleshooting an appliance.

6) Three resistors are connected in parallel. Their values are 12 ohms, 6 ohms, and 2 ohms and they are connected to a 40 v power supply. Find (a) the effective resistance and (b) the current through each resistor.

7) A string of Christmas tree lights contains 20 bulbs in series, each using 7 watts. What is the resistance of each if the applied voltage is 115 v? (By the way, most Christmas tree lights are in parallel, Why?).